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## **Differences in swimming speed on short course and long course for female and male breaststroke swimmers: A comparison of swimmers at national and international level**

P Koch-Ziegenbein <sup>1</sup>, B Knechtle <sup>1,2</sup>, Ch Alexander Rüst <sup>1</sup>, T Rosemann <sup>1</sup>, R Lepers <sup>3</sup>

<sup>1</sup> Institute of General Practice and for Health Services Research, University of Zurich, Zurich, Switzerland

<sup>2</sup> Gesundheitszentrum St. Gallen, St. Gallen, Switzerland

<sup>3</sup> INSERM U1093, Faculty of Sport Sciences, University of Burgundy, Dijon, France

### **Emails:**

Pia Koch-Ziegenbein | inops@web.de

Beat Knechtle | beat.knechtle@hispeed.ch

Christoph Alexander Rüst | christoph.ruest@bluewin.ch

Thomas Rosemann | thomas.rosemann@usz.ch

Romuald Lepers | romuald.lepers@u-bourgogne.fr

### **Research article**

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### **Corresponding author**

PD Dr. med. Beat Knechtle

Facharzt FMH für Allgemeinmedizin

Gesundheitszentrum St. Gallen

Vadianstrasse 26

9001 St. Gallen

Switzerland

Telefon +41 (0) 71 226 82 82

Telefax +41 (0) 71 226 82 72

e-mail: beat.knechtle@hispeed.ch

## Abstract

**Background:** The aims were to examine (i) the difference in swimming speed in breaststroke swimmers between short (SC) and long course (LC) and (ii) the change in swimming speed across years for elite female and male swimmers competing at national and international level.

**Methods:** Swimming speed of breaststroke swimmers at national level (*i.e.* athletes listed in Swiss swimming high score list between 2000 and 2011) and at international level (*i.e.* finalists of World Championships between 2001 and 2012) were analyzed for three course distances (*i.e.* 50m, 100m and 200m) using linear regression analyses and analysis of variance.

**Results:** Swimming speed was faster in SC than in LC in 50m (1.8-2.6%), 100m (2.2-3.6%) and 200m (2.6-4.2 %), respectively. Swimming speed increased between 1.2% and 5.2% both for SC and LC across years, independently of the sex and the distance. For all distances, the sex difference was greater in LC than in SC. Mean values for the sex difference in swimming speed at national level were 12.1% in SC *versus* 11.9% in LC for 50 m, 11.9% in SC *versus* 11.3% in LC for 100m and 11.0% in SC *versus* 10.7% in LC for 200m, with significant difference only for 200m LC ( $p=0.03$ ). Mean values for sex difference in swimming speed at international level were 13.3% in SC *versus* 12.7% in LC for 50m, 12.6% in SC *versus* 11.9% in LC for 100m and 12.1% in SC *versus* 11.2% in LC for 200m, only with significance for 100m SC ( $p=0.01$ ).

**Conclusion:** Elite breaststroke swimmers were ~3% faster on SC compared to LC. The sex difference in breaststroke swimming speed from 50m to 200m events was ~11% (with significance at national level on 200m LC and on international level on 100m SC) but appeared slightly greater in LC compared to SC.

**Keywords:** sex difference, performance, endurance

## Introduction

Indoor swimming competitions are usually held in short course (25m) and long course (50m) pools.<sup>1</sup> Blanksby reported that swimming world records were faster in 25m pools due to the higher number of turns and push offs.<sup>2</sup> The higher number of turns and push offs leads to a redistribution of muscular load, reduced blood lactates and physiological recuperation can occur during the turn.<sup>2</sup> With increasing race distance, swimmers perform more turns on long course than on short course.<sup>2</sup>

Breast stroke is a swim style with a discontinuous technic like butterfly.<sup>3-5</sup> The variation in velocity in breast stroke and butterfly were twice as large as in freestyle swimming.<sup>4</sup> Butterfly presented higher velocity than breast stroke and back stroke. The stroke frequency is also higher than in breast stroke and the stroke length is higher than in crawl.<sup>3</sup> High intracyclic variation in the average impulse can be found in butterfly and breast stroke which results from the large acceleration and deceleration phases within the stroke cycle. Energetic cost is greater in butterfly, followed by breast stroke, back stroke and freestyle.<sup>3</sup>

Breast stroke turns can account to one third of race time in 25m pools in all 200m events and longer.<sup>2</sup> Thereby the oxygen costs through the acceleration are considerably.<sup>4</sup> In breast stroke swimming, velocity increases by increasing stroke frequency and decreasing distance per stroke.<sup>4</sup> Summarizing biomechanical factors such as stroking parameters characterize swimming speed improvements best followed by physical factors like body height and arm-span and physiological factors like peak oxygen consumption.<sup>6-8</sup>

To the best of our knowledge, there were no other studies focusing on (i) the change in swimming speed across years and (ii) the difference in swimming speed between long course and short course only for a single discipline like breaststroke. Therefore, the aims of this study

were to examine (i) the difference in swimming speed between short and long course for breaststroke and (ii) the change in swimming speed in breast stroke swimming across years.

To achieve these aims, we compared the swimming speeds of elite breaststroke swimmers at national level from the Swiss swimming high score list between 2000 and 2011 and at international level from the finals of the FINA World Championships between 2001 and 2012. The advantage of the Swiss data was that they were recorded annually. Data from the world championships were, however, only every two years available.

## Materials and Methods

All procedures used in the study met the ethical standards of the Swiss Academy of Medical Sciences<sup>9</sup> and were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland with a waiver of the requirement for informed consent of the participants given the fact that the study involved the analysis of publicly available data.

### *Data sampling and data analysis*

The data set from this study was obtained for national swimmers from the Swiss Swimming Federation<sup>10</sup> and for international swimmers from the European Swimming Federation<sup>11</sup>. Breaststroke swimmers at national level (*i.e.* athletes ranked in the Swiss swimming high score list between 2000 and 2011) and breaststroke swimmers at international level (*i.e.* finalists from the FINA World Championships between 2001 and 2012) were included. We compared the change in breaststroke swimming speed across years and the difference in breaststroke swimming speed between long course and short course.

The annual top ten (*i.e.* ten fastest swimming times) men and women for the three race distances (*i.e.* 50m, 100m, 200m) were determined for long course and short course and analysed regarding the change in swimming speed and sex difference over time. The annual top ten athletes per sex, distance and course length were pooled (*i.e.* 12 years x 10 athletes = n=120 per distance and course length) and analysed regarding the interaction between sex and course length on swimming speed. In order to increase the comparability of the results with similar studies, all race times were converted to swimming speed prior to analysis. Swimming speed was calculated using the equation  $[\text{swimming speed in m/s}] = [\text{race distance in m}] / [\text{race time in s}]$ . The sex difference in performance was calculated using the equation  $([\text{swimming speed in women}] - [\text{swimming speed in men}]) / [\text{swimming speed in men}] \times 100$ ,

where sex difference was calculated for every pairing of equally placed athletes (*e.g.* between men and women 1<sup>st</sup> place, between men and women 2<sup>nd</sup> place, etc.) before calculating mean value and standard deviation of all the pairings. In order to facilitate reading all sex differences were transformed to absolute values prior to analyses. To compare top swimming speed between long course and short course swimmers, the overall top ten (*i.e.* ten fastest swimming speed) female and male swimmers from the Swiss swimming high score list between 2000 and 2011 and the eight finalists from the FINA World were determined for long course and for short course swimming and compared regarding swimming speed and sex difference.

### ***Statistical analysis***

In order to increase the reliability of the data analyses, each set of data was tested for normal distribution as well as for homogeneity of variances prior to statistical analyses. Normal distribution was tested using a D'Agostino and Pearson omnibus normality test and homogeneity of variances was tested using a Levene's test in case of two groups and with a Bartlett's test in case of more than two groups. Linear regression was used to find significant changes in a variable across years. A Student's *t*-test with Welch's correction in case of unequal variances was used to find significant differences between two groups. A one-way analysis of variance (ANOVA) with subsequent Dunnett post-hoc analysis was performed to find significant differences between more than two groups (*i.e.* the fastest age group and the other age groups). A two-way-ANOVA (sex  $\times$  course length) was performed to determine the interaction between sex and course length on swimming speed. Statistical analyses were performed using IBM SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, La Jolla, CA, USA). Significance was

accepted at  $P < 0.05$  (two-sided for  $t$ -tests). Data in the text are given as mean  $\pm$  standard deviation (SD).



## Results

Data from the Swiss swimming high score list were available from 26,556 athletes, including 13,277 women and 13,279 men on short course and from 25,111 athletes, including 12,627 women and 12,484 men on long course. Data from 125 finalists from the FINA World Championships were available, including 56 women and 69 men on short course and from 112 athletes, including 54 women and 58 men on long course.

### *Comparison of swimming speed in breaststroke between short and long courses*

Swimming speed was faster on short than on long course for 50m, 100m and 200m for both courses. Differences in swimming speed between 25m and 50m pools for the elite Swiss swimmers were  $2.7\% \pm 0.9$  [range 1.8-3.6%] (Table 1). The mean differences in swimming between 25m and 50m pools at the FINA World Championships were  $3\% \pm 1.15$  [range 1.9-4.2%] (Table 2).

### *Change in breaststroke swimming speed across the years*

Breaststroke swimming speed increased for both short and long courses over the years independent of sex and race distance for both courses. Male Swiss swimmers improved swimming speed significantly by 1.2% ( $p=0.04$ ) on 50m short course and 2.63% ( $p=0.03$ ) in 100m short course. Female Swiss swimmers improved swimming speed significantly by 2.78% ( $p=0.004$ ) on 50m long course, by 3.03% ( $p=0.01$ ) on 100m long course and by 4.09% ( $p=0.04$ ) on 200m long course. Male Swiss swimmers showed a significant improvement of 2.44% ( $p=0.0003$ ) in 50m long course, 3.36% ( $p=0.01$ ) in 100m long course and 5.15% ( $p=0.003$ ) in 200m long course, respectively (Figure 1 and Table 3).

The mean improvement of the two distances for men on short course was  $1.9\pm0.7\%$  and of the three distances for long course  $3.6\pm1.1\%$ . The mean improvement of the three distances for women on long course was  $3.3\pm0.6\%$ .

Figure 3 and Table 4 show the same trend for the FINA World Championships. Female swimmers at international level improved swimming speed significantly by 2.4% ( $p=0.0183$ ) on 50m short course, by 3.4% ( $p=0.0023$ ) on 100m short course and by 2.8% ( $p=0.0138$ ) on 200m short course, respectively. Male swimmers showed a significant improvement by 2.7% ( $p=0.0168$ ) on 50m short course, by 2.9% ( $p=0.0023$ ) on 100m short course and by 3.8% ( $p=0.01$ ) on 200m short course, respectively. Women achieved a significant improvement of 2.5% ( $p=0.02$ ) on 50m long course and 2.7% ( $p=0.03$ ) on 100m long course.

The mean improvement in three distances for men on short course was  $3.19\pm0.5\%$ . The mean improvement of the three distances for women on short course was  $2.9\pm0.5\%$ . Women showed a mean improvement of  $2.6\pm0.1\%$  on long course during the studied period.

### ***Sex difference in breaststroke swimming speed***

For all distances, the sex difference in breaststroke swimming speed was greater on short than on long course (Table 1 and 2). The sex difference in swimming speed at national level was on average  $11.3\pm1.6\%$  [range 9.7-12.9%] (Table 1 and Figure 2). Among the finalists from the World Championship the sex difference was higher on short course than on long course, too. The sex difference in swimming speed was on average  $12.3\pm1.1\%$  [range 11.2-13.3%] in all three distances.

Figure 2 shows that the longer the swim distance the lower the sex difference in swimming speed. Women at national level were 14% slower than men on short course and 13% slower on long course, with a significant difference in 200m long course ( $p=0.03$ ). In finalists from

the World Championship, the sex differences were higher, but not significant, on 50m short than on 50m long course to (Figure 4). Women were 11.8% slower than men on short and 11.1% slower on long course, with no difference for 50m short course (*i.e.* with significant difference in 100m 10.7% *versus* 10.3%  $p=0.01$ ; 200 m 11% *versus* 9.7%, no significance).

## Discussion

The aims of this study were to examine (i) the difference in breaststroke swimming speed between short and long course and (ii) the change in swimming speed across the years in elite swimmers at both national and international level. The main findings of this study were (i) breaststroke swimming speed was 1.8-4.2% faster on short than on long course, (ii) swimming speed improved for both short and long course during the last decade independently of sex and race distance, (iii) the sex difference in swimming speed was greater on short than long course for all distances, and (iv) the longer the distance the more the sex difference in swimming speed decreased.

### *Breaststroke swimming speed was faster on short than on long course*

Swimming speed was faster on short than on long course for 50m, 100m and 200m. Due to the higher number of turns and push offs swimming speed is faster on short than on long course.<sup>2</sup> Breaststroke turns can account to one third of race time in 25m pools.<sup>2</sup> The anaerobic metabolism predominates on short events.<sup>5, 12</sup> This means an improvement in short events can be achieved by enhancement of anaerobic training.<sup>5</sup> The connection between local fatigue due to increasing lactate values and increasing energy costs may explain the decrease in swimming skills.<sup>13</sup> Stroke length decreases dramatically at a given lactate value and stroke rate increases in anaerobic sections.<sup>3, 14</sup> Therefore, the longer the race the lower the velocity<sup>15</sup> which can be shown in our results.

### *Improvement in breaststroke swimming speed across the years*

The second important finding was that swimming speed increased in both women and men on both courses over the years for swimmers at both national and international level. However,

the improvements in swimming speed in athletes at international level were lower compared to swimmers at national level. Competitors at international level are closer on the maximum physiologically possible human frontiers<sup>16</sup> so they cannot improve as much as national swimmers.

In addition to changes in anthropometric characteristics<sup>17, 18</sup>, improvements in training<sup>17, 19</sup>, and psychological aspects<sup>17</sup> a new generation of swimsuits affected swimming speed.<sup>20</sup> Wearing this new full-body swim suits reduced passive drag.<sup>19</sup> This was associated with a decreased energy cost and an increased distance per stroke.<sup>20</sup> Although FINA prohibited wearing full-body wetsuits, swimming speed did not fall.<sup>19</sup> The reason could be the use of new angled starting blocks, where the kick start was significantly faster than on the older starting blocks.<sup>21, 22</sup>

### ***Sex difference in breaststroke swimming speed in short versus long course***

The third important finding was that the sex differences in swimming speed were greater in short than in long course. Women achieved approximately 90% of the swimming speed of men in short course which is in line with international data. Sharp et al.<sup>23</sup> described that world records were faster in 25m pools than in 50m pools due to more turns and push offs and reduced blood lactate values.<sup>24</sup> Additionally, the turns lead to a redistribution of the muscular load and physiological recuperation can occur.

Swimmers seemed to have improved their technic of turns over the years as well as their anaerobic performance (*i.e.* sprint).<sup>2, 12</sup> The decrease in velocity on long course could be related to the fact that endurance performance suffered due to the improved anaerobic performance due to larger muscle mass. This means the longer the course the higher the muscle fatigue which might impair the swimming technic because of less streamlining

resulting in increasing drag. Thereby an increase in energy cost and velocity cannot be sustained.<sup>13, 14</sup>

The fourth important finding was the longer the competition distance the lower were the differences in swimming speed between men and women. Lower energy costs are reported for women due to anthropometric values for long distances in swimming.<sup>25</sup> Women have a lower hydrodynamic resistance and are more streamlined than men.<sup>25</sup> Zuniga et al.<sup>18</sup> suggested that women could improve their performances by reducing body fat, because a greater percentage of body fat may adversely affect swimming speed. Additionally, they have to build up fat-free weight to generating power.

The aerobic capacity is the main base for endurance performance.<sup>26</sup> High endurance allows maintaining a high average velocity. Lower lactate levels were reported for women after competitions, which means a slower fatigue.<sup>13</sup> Women competing at national level may have to have a higher percentage of slow twitch fibers and thereby improve endurance performance on the long course.<sup>12</sup> Or they take more advantage of turns with longer wall push-off times resulting in faster final push-off velocities.<sup>2</sup> The maximum power depends on metabolic energy, which depends on the anthropometric and technical character of the athlete.<sup>6</sup> In well trained swimmers, the size scaled cost of swimming is not depending upon age and sex.<sup>27</sup> Additionally, psychological aspects may play a role<sup>17</sup> and the greater expectation to win.<sup>28</sup>

## **Conclusion**

Elite breaststroke swimmers at both national and international level were ~3% faster in 25m pools compared to 50m pools for distances between 50 and 200m, breaststroke swimming speed increased on short and long course over the years between 1.2% and 5.2% in elite swimmers competing at both national and international level independently of the sex and the distance. The sex difference in breaststroke swimming speed from 50m to 200m was close to 11% but appeared slightly greater in 50m pools compared to 25m pools. Future studies should investigate sex differences in short and long course for other swim strokes.

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<b>Distance and sex</b>	<b>Short course (m/s)</b>	<b>Long course (m/s)</b>	<b>Absolute Difference (m/s)</b>	<b>Difference in percent (%)</b>
50m women	1.49± 0.03	1.46±0.02	0.03	1.8
50m men	1.69±0.03	1.66±0.02	0.03	2.0
100m women	1.38±0.02	1.34±0.02	0.04	2.9
100m men	1.56±0.03	1.51±0.02	0.06	3.6
200m women	1.28±0.02	1.24±0.02	0.04	2.8
200m men	1.43±0.03	1.39±0.02	0.05	3.2

**Table 1** Mean swim speed of the annual top ten women and men Swiss athletes in breaststroke swimming in 50m, 100m and 200m in short course and long course

<b>Distance and sex</b>	<b>Short course (m/s)</b>	<b>Long course (m/s)</b>	<b>Absolute Difference (m/s)</b>	<b>Difference in percent (%)</b>
50m women	1.68±0.01	1.65±0.01	0.03	1.9
50m men	1.90±0.01	1.85±0.01	0.05	2.6
100m women	1.55±0.01	1.52±0.01	0.03	2.2
100m men	1.74±0.01	1.70±0.01	0.05	2.7
200m women	1.45±0.02	1.41±0.00	0.04	2.6
200m men	1.62±0.01	1.56±0.01	0.07	4.2

**Table 2** Mean swimming speed of the top eight women and men in World Championship in breaststroke swimming in 50m, 100m and 200m in short course and long course

Distance and sex	Short course increase absolut	Long course increase absolut	Short course increase relative	Long course increase relative	Significance p	
	(m/s)	(m/s)	%	%	Short course	Long course
50m women		0.04		2.78+0.57		0.0048
50m men	0.02	0.04	1.20-0.7	2.44+1.13	0.0495	0.0003
100m women		0.04		3.03±0.57		0.0113
100m men	0.04	0.05	2.63+0.7	3.36±1.13	0.0311	0.0132
200m women		0.05		4.09-0.57		0.0417
200m men		0.07		5.15-1.13		0.0038

**Table 3** Change in swimming speed of the annual top ten women and men at national level in breaststroke swimming in 50m, 100m and 200m in short course and long course. The missing data were not included because they were not significant

Distance and sex	Short course increase absolut	Long course increase absolut	Short course increase relative	Long course increase relative	Significance p	
	(m/s)	(m/s)	%	%	Short course	Long course
50m women	0.04	0.04	2.45+0.46	2.53+0.1	0.0183	0.0247
50m men	0.05		2.73+0.48		0.0168	
100m women	0.05	0.04	3.36±0.46	2.74-0.1	0.0023	0.0269
100m men	0.05		2.98±0.48		0.0023	
200m women	0.04		2.88-0.46		0.0138	
200m men	0.06		3.85-0.48		0.0145	

**Table 4** Change in swimming speed of the top eight women and men athletes between 2001-2012 (World Championship, took place alternately on short course and long course) in breaststroke swimming in 50m, 100m and 200m in short course and long course. The missing data were not included because they were not significant

## Figure Captions

**Figure 1** Swimming speed of the annual top ten women (Panels A, C, E) and top ten men (Panels B, D, F) competing at national level in breaststroke swimming in 50m (Panels A, B), 100m (Panels C, D) and 200m (Panels E, F) in short course and long course.

**Figure 2** Swimming speed and sex difference of the overall top ten female and male breaststroke swimmers in 50m (Panel A), 100m (Panel B), and 200m (Panel C) competing at national level between 2000 and 2011. The p-value is given in case of a significant difference between short course and long course swimming. 'NS' means no significance and indicates absence of significant difference.

**Figure 3** Swimming speed of the annual top eight women (Panels A, C, E) and men (Panels B, D, F) competing at international level between 2001 and 2012 in breaststroke swimming in 50m (Panels A, B), 100m (Panels C, D) and 200m (Panels E, F) in short course and long course.

**Figure 4** Swimming speed and sex difference of the overall top ten men and women breaststroke swimmers in 50m (Panel A), 100m (Panel B), and 200m (Panel C) competing at international level between 2001 and 2012. The p-value is given in case of a significant difference between short course and long course swimming. 'NS' means no significance and indicates absence of significant difference.

**Figure 1**



**Figure 2**

**Figure 3**

